Army Research Laboratory

User's Manual for the Mobile Optical Detection System (MODS)

by Laurel C. Sadler and Dr. Troy Alexander

ARL-MR-0805 **January 2012**

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory
Adelphi, MD 20783-1197

ARL-MR-0805 **January 2012**

User's Manual for the Mobile Optical Detection System (MODS)

Laurel C. Sadler and Dr. Troy Alexander
Computational and Information Sciences Directorate, ARL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
January 2012	Final	

4. TITLE AND SUBTITLE
User's Manual for the Mobile Optical Detection System (MODS)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Laurel C. Sadler and Dr. Troy Alexander

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
ATTN: RDRL-CII-A
2800 Powder Mill Road
Adelphi, MD 20783-1197

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-MR-0805

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report briefly describes the hardware and software integration of a novel optical augmentation (OA) sensor based on a commercial-off-the-shelf charged-coupled-device (CCD), a three-diode laser (one ultraviolet [UV]/two near infrared [NIR]), and a pan/tilt device along with signal processing software to realize a real-time OA sensor for counter-intelligence, surveillance, reconnaissance (ISR) applications. This system is called the Mobile Optical Detection System (MODS). This report provides a user's manual for the Soldier/MODS operator. The MODS control software and graphical user interface is discussed in detail. The control software allows for automation of the surveillance system, the flexibility of accommodating various observation and target scenarios, as well as the ability to record video data. It provides the location of the optical return in terms of azimuth and elevation. This document explains, from an operator's perspective, how to set up the system for various scenarios including day/night and near/far surveillance. It also describes how to modify several parameters to enhance the performance of the image processing software and allow for use of any number of lasers.

15. SUBJECT TERMS
Optics, retro-reflector, laser diodes

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Laurel C. Sadler
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (*Include area code*)
Unclassified	Unclassified	Unclassified	UU	18	(301) 394-1221

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

1. Introduction

This report briefly describes the hardware and software integration of a novel optical augmentation (OA) sensor based on a commercial-off-the-shelf charged-coupled-device (CCD), a three diode laser (one ultraviolet [UV]/two near infrared [NIR]), and a pan/tilt device along with signal processing software to realize a real-time OA sensor for counter-intelligence, surveillance, reconnaissance (ISR) applications. This system is called the Mobile Optical Detection System (MODS).

For more information on the laser implementation, scientific background, and field test results, see reference 1. The emphasis of this report is to provide a manual for the end user.

2. Capabilities and Specifications

The MODS is designed to be a lightweight and mobile system with 1-km range. It can support multiple missions including improvised explosive device (IED) event detection, force protection, and insurgent ISR detection. The laser is not visible to the human eye; therefore, position is not compromised. It provides the location of the optical return in terms of azimuth and elevation. It can be set for continuous surveillance over a large area, halting the system and sounding a bell when acquiring a target, which will allow the Soldier to focus on additional tasks.

3. Technical Objectives

The MODS integrates a digital camera, three lasers of varying wavelengths, a pan/tilt device, and image processing software. The digital camera and three lasers of varying wavelengths were assembled in a box and mounted on a pan/tilt device. The control software allows for automation of the surveillance system, the flexibility of accommodating various observation and target scenarios, as well as the ability to record video data.

4. Hardware Integration

The MODS sensor head was mounted onto a heavy-duty pan/tilt device to facilitate operation in an Army-relevant environment. The sensor head was integrated onto a pan/tilt device with a payload capacity greater than 220 kg, 355° pan range and 45° tilt range, as shown in figure 1.

Figure 1. (a) Rear view of MODS showing electrical transits for laser power supply, laser transistor-transistor logic (TTL) modulation, and CCD power supply. (b) Front view of MODS showing window which facilitates target illumination and detection return.

5. Software Integration

The system control software and the graphical user interface (GUI) were developed in C# using Microsoft Visual Studio in a MS Windows environment. The control software integrates the operation and manages the control sequence of the CCD receiver, the three laser diodes, a pan/tilt device, and the image processing algorithms to achieve the automated MODS. Automation is achieved by configuring the system with the aid of the GUI to survey a selected area using the pan/tilt device. The software consists of three parts: (1) the control sequence software and image processing algorithms, (2) the user interface, and (3) the hardware drivers. There are three separate hardware drivers that (1) control the pan/tilt device, (2) provide TTL modulation to the laser diodes via a parallel port, and (3) digitize images, used for target detection, from the CCD receiver.

The user interface allows the operator the flexibility to set up the MODS for surveillance in multiple configurations. Moreover, the interface allows the operator to choose which combination of lasers to use for target detection and modify various parameters within the image processing algorithms to allow for enhanced target detection. These and other features of the system are described in more detail in section 6.

6. MODS Control Software and Image Processing

The MODS software acquires an image from the digital camera. This is the background image used in the image processing algorithm. The first laser is turned on and a second image (laser 1 image) is acquired from the camera. The software then turns off the first laser, turns on the second laser, and acquires a third image (laser 2 image) from the camera. This process is repeated for the third and final laser acquiring the laser 3 image. The background image is then subtracted from each laser image acquired providing three sets of target information. In order to reduce false alarms, these three sets of target information are combined to generate one final set of target information to be displayed and recorded. The subtraction algorithm being used allows for adjustment to the size and shape of the target as well as clutter and contrast thresholds.

The MODS can be configured to survey a selected area using the pan and tilt device. The minimum and maximum angle in increments of 0.5° for both; the pan and the tilt can be set to allow the system to monitor a larger area. The system automatically cycles through each position performing the previously described image processing procedure at each location within the surveillance region. Upon identification of a target, the motion of the pan/tilt device is halted, a bell is sounded and the system continues to display the video, the targets, and target locations to the operator and/or saved to a file. This designated surveillance region can be scanned continuously or a single time. The pan/tilt device can also be set to a constant position for continuous surveillance at that location.

7. User Interface

The MODS software initializes in a mode convenient for system configuration. When initially starting the system, raw images from the digital camera are displayed in the First Quadrant allowing the operator to adjust the gain, exposure, and focus of the camera. The operator can also use the pan/tilt controls to view an area of interest.

The GUI interface (figure 2) was designed to have the flexibility to allow the operator to set up the MODS for surveillance in a variety of configurations. These configurations include positioning the MODS in a designated direction to survey and area without moving the pan and tilt; presetting a larger area for observation while using the pan and tilt device in an automated configuration; and, within these two scenarios, allowing the ability to select which combination of lasers to be used for detection. The user interface also allows the operator to modify five parameters of the image processing software making the system flexible to target shape, size, and reflectivity.

The GUI is broken into four main sections and an Exit button. The upper left (first) quadrant displays the background or raw image from the camera, the upper right (second) quadrant displays one of three processed images, the lower left (third) quadrant contains all the controls for the system, and the lower right (forth) quadrant displays output information from the system.

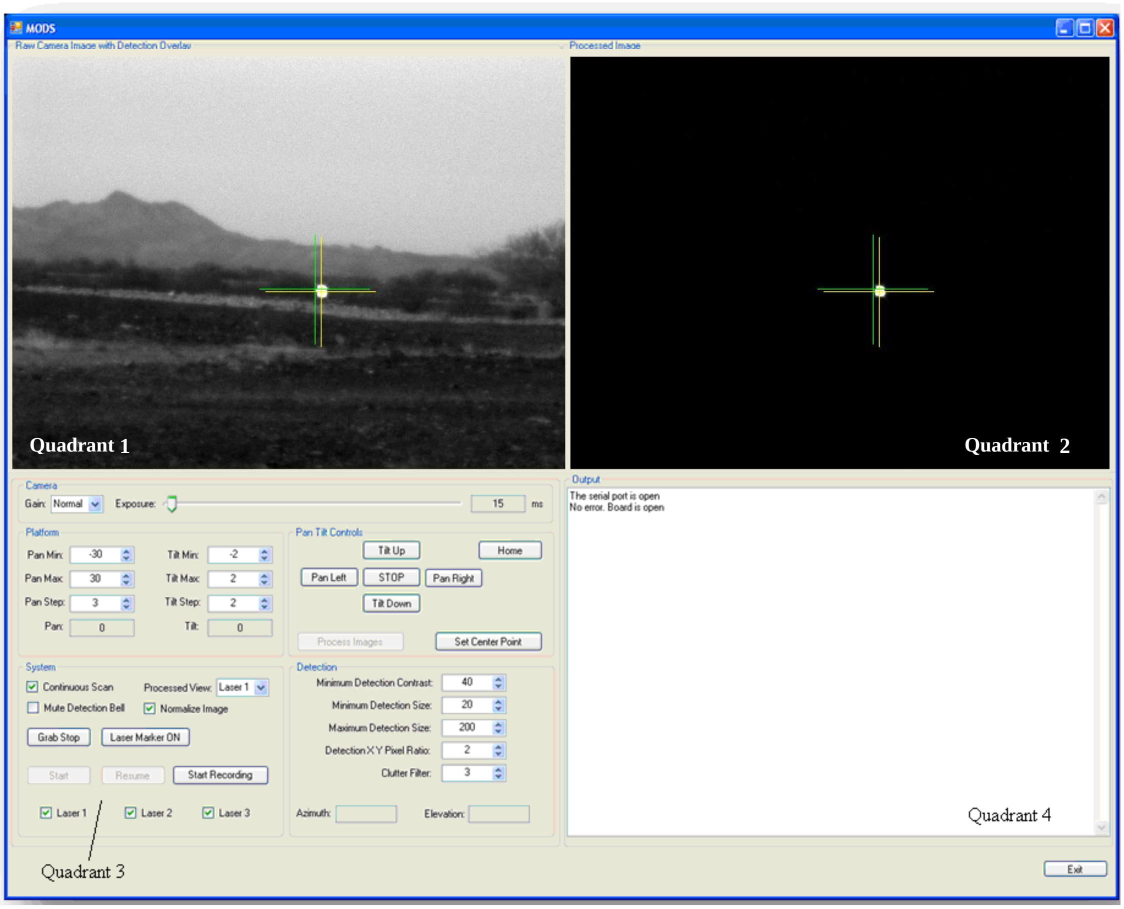

Figure 2. MODS user interface.

7.1 First Quadrant

This quadrant displays the background or raw image acquired from the digital camera. When targets from the combined laser images are detected, they are displayed in this window with a rectangle around the target along with the relative azimuth and elevation information associated with the target. The azimuth and elevation of these targets is also displayed in the output panel in the fourth quadrant.

The first quadrant can also be used to mark the bore sight crosshair or the actual location at which the laser is firing. This is accomplished with a simple click of the mouse button. The bore sight crosshair can be set or moved by placing the mouse pointer on the desired location in the Raw Image Panel and clicking the left mouse button. This *x-y* parameter is saved into a startup file that is automatically reloaded when restarting the MODS system. This capability saves the operator from having to recalibrate the bore sighting each time the system is restarted.

7.2 Second Quadrant

This quadrant displays one of the three processed images. The displayed image is the result of the subtraction algorithm on the background image and the selected laser image. If the image processing performed on the selected laser and background images produce targets, they are displayed with crosshairs and the relative azimuth and elevation data in this window. The crosshairs and relative location data for laser 1 are violet, for laser 2 are red, and laser 3 are Indian red (light red). Associating each laser with a unique color assists the operator to rapidly discern which processed laser image is being viewed.

7.3 Third Quadrant

The third quadrant (figure 3) contains the controls for the entire MODS. It is the most complicated quadrant and is broken into five smaller control panels including Camera, Platform, Pan Tilt Controls, System, and Detection. The buttons, check boxes, and drop-down menus in this quadrant are disabled if they are not to be accessed while the various processes are running.

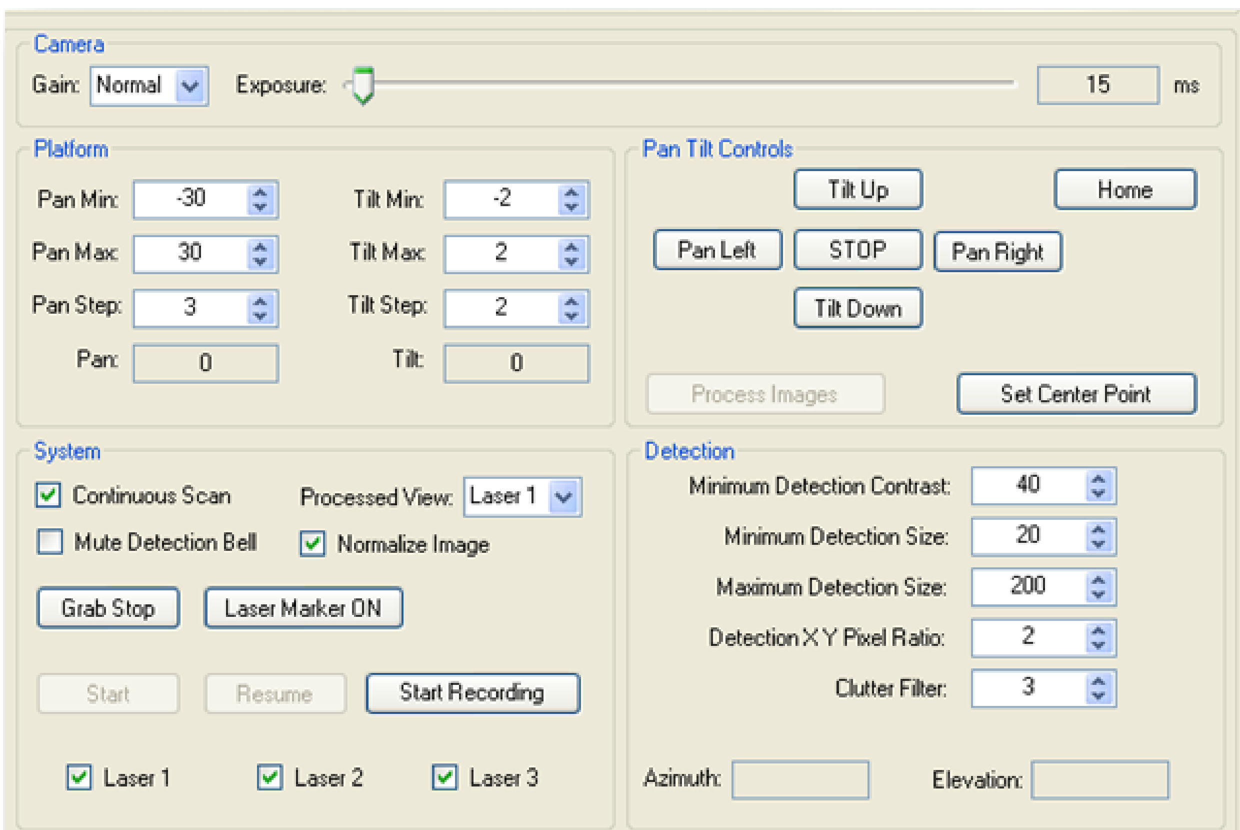

Figure 3. Third quadrant.

7.3.1 Camera

The camera control panel allows the operator to send commands directly to the digital camera. The operator can change the gain of the camera from normal to high using the drop-down menu box. The slider bar, in combination with the text box, allows the operator to adjust the exposure time (microseconds) of the camera. The operator can choose to move the slider bar or enter the exposure time directly into the text box. Modification both the gain and the exposure is allowed while processing and displaying images.

7.3.2 Platform

The platform panel allows the operator to set up the MODS for surveillance of a larger area. The three Pan drop-down menu boxes allow the operator to set a minimum angle, maximum angle, and a step increase angle for panning the pan/tilt device. The three Tilt drop-down menu boxes allow the operator to set a minimum angle, maximum angle, and a step increase angle for tilting the pan/tilt device. The Pan and Tilt text boxes continually update displaying the current angle of azimuth and elevation of the pan/tilt device.

7.3.3 Pan/Tilt Controls

The pan/tilt control panel contains all the buttons to control the pan/tilt device. Each press of the Tilt Up button or Tilt Down button allows the operator to tilt the pan/tilt device one increment in the desired direction. The angle size of this increment is specified by the Tilt Step size in the Platform panel. Each press of the Pan Left button or Pan Right button allows the operator to pan the pan/tilt device one increment in the desired direction. The angle size of this increment is specified by the Pan Step size in the Platform panel. The STOP button allows the operator to send a stop command to the pan/tilt device at any time. The STOP button is always enabled. The Set Center Point button allows the operator to set a (0, 0) or home point for azimuth and elevation. This center point is then used by the Home button to return the pan/tilt device back to its (0, 0) position. The Process Images button allows the operator to acquire images, fire the lasers, and process the images for target detections without moving the pan/tilt device once it has been pointed in the desired direction. Once this process is started the Process Images button becomes the Stop button, which ends this process when clicked.

7.3.4 System

The System panel allows the operator to manipulate many aspects of the MODS. The Continuous Scan check box allows the operator to choose to scan the area selected in the Platform panel repeatedly when checked or one single scan from min to max of pan and tilt if not checked. When checked, the Mute Detection Bell check box silences the bell sounded when a target is detected. The Processed View drop-down menu box allows the operator to select which laser image to be displayed in the Processed Image panel of the second quadrant. This displayed image is actually the result of the image detection algorithm (subtraction algorithm) on the background image and the selected laser image. The Normalize Image check box, if checked, allows the operator to view the image being displayed in the Raw Image Panel of the First Quadrant after normalizing the image. The normalization is for display only and does not affect the image data being used by the target detection algorithm.

The Grab Images button allows the operator to view images acquired by the camera without firing the lasers or performing the image processing. This feature allows the operator to view images while focusing the camera or planning the area of surveillance. The Grab Images button becomes the Grab Stop images button, which will stop the camera from acquiring images when clicked. The MODS starts up with the Grab Images button selected. The operator must click the Grab Stop button to end the process of acquiring and displaying images before beginning either of the target acquisition processes by clicking the Process Image button in the Pan Tilt Controls panel or the Start button in the System panel.

The Laser Marker ON/OFF button allows the operator to view or not view the bore sighting crosshair in the Raw Image panel of the First Quadrant.

The Start button in this panel starts the complete MODS surveillance system, moving the pan/tilt device through the various locations designated by the information input into the platform panel. The pan/tilt device continues to move through its various settings until it detects a target. At this time, the device stops panning and tilting, and continues the processes of firing the lasers and processing the images pointing only in that direction until the Resume button is clicked. When the Resume button is clicked, the pan/tilt device continues stepping through its various locations until it detects another target. The Start button becomes the Stop button, which ends the above process when clicked.

The Start Recording button saves the images, as well as any bore sighting crosshairs, target rectangles, and target azimuth and elevation data, being displayed in the Raw Image Panel of the First Quadrant to a file selected using a pop-up file select window (figure 4). The Start Recording button becomes the Stop Recording button, which is clicked when the operator no longer wants to record the data.

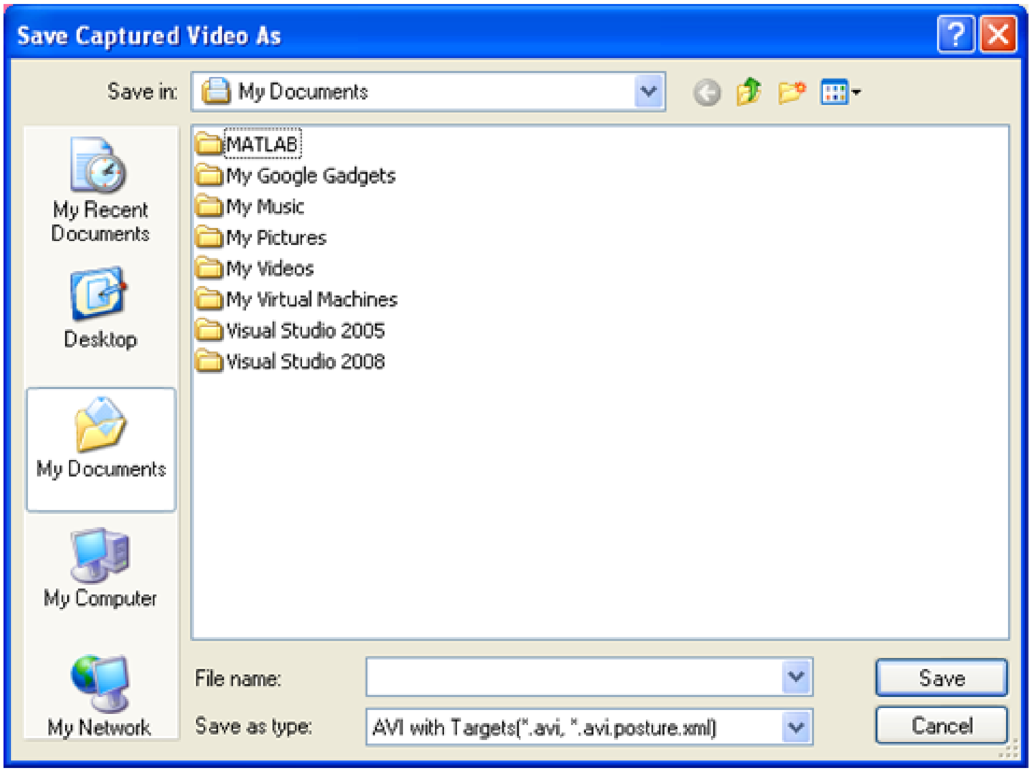

Figure 4. File select pop-up.

The Laser check boxes denote which lasers will be included in the system configuration. Laser 1, Laser 2, and Laser 3 are fired and used in the final combination for a true detection only when its corresponding check box is checked. A true detection is defined as one in which a retro-reflection is received from all the lasers selected.

7.3.5 Detection

The Detection panel allows the operator to modify five variables used by the image processing and target detection algorithm. Using a drop-down menu box the operator can change the value for minimum detection contrast, minimum target detection size (pixels), maximum target detection size (pixels), and the *x*-*y* pixel ratio of a desired target, as well as adjust the parameters of a clutter (low pass) filter. These variables help to eliminate false alarms.

The Minimum Detection Contrast variable eliminates targets whose reflection does not reach a minimum threshold for brightness.

The Minimum Detection Size variable eliminates reflections that are too small to be considered valid targets. The Maximum Detection Size variable eliminates reflections that are too large to be considered valid targets. The ability to modify the valid detection size variables allows the system more flexibility in accommodating various ranges from the area of surveillance and target scenarios.

The Detection X-Y Pixel Ratio variable to eliminate reflections based on shape. For example, if the desired target is circular, then setting the X-Y Pixel Ratio to 1.5 or 2 will eliminate false alarms that are long and thin and could be caused by edges.

The Clutter Filter variable is used by the low pass filter of the image processing algorithm. It ranges from 0 to 100. A larger value results in stronger filtering. A value of zero turns the filtering off.

The text boxes in this panel display the azimuth and the elevation of the location of the most recent target detected.

7.4 Fourth Quadrant

This quadrant displays output information from the MODS such as errors, camera control feedback, and pan/tilt device feedback. Most importantly to the operator, it displays azimuth and elevation of the detected targets which are displayed in the first quadrant.

8. Exit Button

The exit button shuts down the system when clicked, if all processes have been stopped. If the exit button is clicked while any of the processes are in progress, it has a safety feature of a pop-up box (figure 5) notifying the operator that processes are still running. The pop-up box allows the operator to click the Cancel button, which allows the operator to continue working on the MODS or click the OK button, which properly ends all processes in progress before shutting down the MODS.

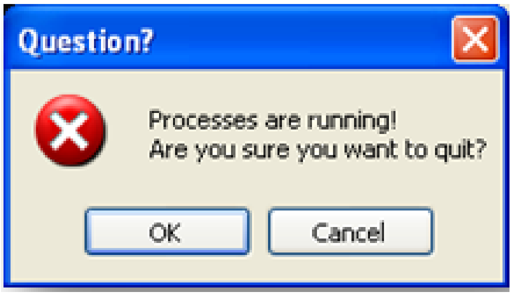

Figure 5. Exit pop-up.

9. References

1. Sadler, Laurel C.; Alexander, Dr. Troy. Mobile Optical Detection System for Counter Surveillance. *Proc. of SPIE Vol. 7694, Ground/Air Multi-Sensor Interoperability, Integration, and Networking for Persistent ISR*, Orlando, FL, April 2010.

List of Symbols, Abbreviations, and Acronyms

CCD	charged-coupled-device
GUI	graphical user interface
IED	improvised explosive device
ISR	intelligence, surveillance, reconnaissance
MODS	Mobile Optical Detection System
NIR	near infrared
OA	optical augmentation
TTL	transistor-transistor logic
UV	ultraviolet

NO. OF COPIES	ORGANIZATION
1 ELEC	ADMNSTR DEFNS TECHL INFO CTR ATTN DTIC OCP 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
10	US ARMY RSRCH LAB ATTN IMNE ALC HRR MAIL & RECORDS MGMT ATTN RDRL CII B L SADLER ATTN RDRL CII A S YOUNG H NGUYEN P DAVID ATTN RDRL CII B LARRY TOKARCIK ATTN RDRL CIO LL TECHL LIB ATTN RDRL CIO MT TECHL PUB ATTN RDRL SEE E T ALEXANDER ATTN RDRL SEE E KEITH ALIBERTI ADELPHI MD 20783-1197
2	US ARMY RSRCH LAB ATTN RDRL SES P WILLIAM D. LUDWIG MICHAEL V. SCANLON ADELPHI MD 20783-1197
1	US ARMY RESEARCH LAB ATTN RDRL-SES JOHN EICKE CHIEF SIGNAL & IMAGE PROCESSING DIVISION ADELPHI MD 20783-1197
1	US ARMY RESEARCH LAB ATTN RDRL-CI JOHN PELLEGRINO CHIEF COMPUTATIONAL SCIENCES DIVISION ADELPHI MD 20783-1197
1	US ARMY RESEARCH LAB ATTN RDRL-CI BARBARA BROOME CHIEF INFORMATION SCIENCE ADELPHI MD 20783-1197